

# **SAVAGE RESERVOIR TEMPERATURE MODEL**

Prepared for

Maryland Department of Natural Resources  
Fisheries Service  
Tawes State Office Building  
580 Taylor Avenue  
Annapolis, MD 21401

Prepared by

Stephen Schreiner

Versar Inc.  
9200 Rumsey Road, Suite 100  
Columbia, MD 21045

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## INTRODUCTION

Increased water appropriations and requests for whitewater discharges from Savage Reservoir have prompted concerns at Maryland DNR-Fisheries Service (MDNR-FS) that there could be insufficient coldwater storage in the reservoir to maintain the trout fishery downstream of the reservoir and into the north branch of the Potomac River. The Interstate Commission on the Potomac River Basin (ICPRB) has created a version of its PRRISM model to estimate total volume of storage which would be used by increased appropriations and releases. ICPRB has also proposed some drought predictive measures to be used to reduce water withdrawals during drought conditions. However, ICPRB's analysis only evaluated total water volume and not coldwater storage. MDNR-FS would like to evaluate the potential for depletion of cold water for downstream fisheries even if there is sufficient total volume available in the reservoir.

MDNR-FS would like to maintain river temperature at or below 68 °F from the dam downstream to the Potomac River to sustain a coldwater fishery during the summer period from June through September. Since there is the potential for warming of river water as water moves downstream from the dam, the release temperature should be no warmer than about 60 °F to allow for heating during low-flow, warm summer conditions while maintaining suitable coldwater fishery habitat conditions in the river.

Available data for developing an analytical coldwater storage model include the following:

- Savage Reservoir storage/elevation values
- Approximately monthly to biweekly reservoir temperature profile data at 3 stations from near the dam to the upper end, for the years 1989, 1990, 1991, 1998, 2008, and 2009
- Hourly to daily flow data from USGS gage below the dam, as an estimate of outflows, 1985-2009
- Hourly to daily temperature downstream of the dam at the USGS gage, 1985-2009
- Elevations of discharge locations in the reservoir
- Daily storage and resulting pool elevation

Table 1 presents the relative amounts of reservoir releases during the months of June through September, about a 120-day period. (End of September was chosen as the end of the summer period, after which temperature of reservoir outflows would not be needed to maintain cool water habitat downstream.) These data indicate the requested flow increase is a relatively small percentage of the reservoir volume potentially available, as compared with the minimum flow and the whitewater flows typically made during the summer months. However, the minimum flow is necessary both to maintain physical habitat as well as the thermal habitat in the river downstream of the dam. All of these releases are assumed to come from the bottom of the reservoir and therefore use whatever coldwater storage is available.

Table 1. Savage Reservoir volume and potential outflows during the summer months (June through September).		
Reservoir/outflow Category	Volume, acre-feet	% of Reservoir Volume
Reservoir total, full pool (elevation 1468.5 ft.)	18833 (1.5 ft below spillway)	
55 cfs minimum flow	10016	70.5
Whitewater flows, 3 days @ 1000 cfs for 6 hours each	1488	7.9
2.75 mgd increase	776	5.5
Total outflows (assuming no spillage)	12280	83.9

Table 2 lists available reservoir profile temperature data and the average inflow and outflow for the period of interest of June through September of each year, the most critical period of interest for trout habitat.

Table 2. Savage Reservoir Model – temperature data available and average flow rates by year				
Year	Temperature Data Available – Date Range and Number of Profiles	Average Inflow 1Jun-30Sep (cfs at Barton gage prorated by ICPRB)	Average Outflow 1Jun-30Sep (cfs, downstream gage from ICPRB)	Inflow Rank (1=driest)
1989	18Apr-18Sep, 11	108	147	70 (very wet)
1990	23May-21Sep, 9	81	151	58 (wet)
1991	23May-24Sep, 6	8	55	1 (very dry)
1998	29Apr-21Sep, 7	42	81	35 (average)
2004	4Aug-3Nov, 2	101	114	68 (very wet)
2005	20Apr-17Aug, 2	20	54	11 (dry)
2008	13May-14Oct, 12	95	107	66 (very wet)
2009	27Apr-30Sep, 12	33*	94*	- (average-dry)
Average 1930-2008 (inflow); 1949-2008 (outflow)		59	90	
Median 1930-2008 (inflow); 1949-2008 (outflow)		47	77	
* Flow not adjusted, pending update from ICPRB. USGS reports average daily flow at the Barton gage for these months for the period of record, as 46 cfs				

Based on available data, the worst-case year to use with available temperature data is 1991. 2008 and 2009 were wet and average-to-dry, respectively, although the reservoir elevation patterns were unusual in both recent years due to lowered levels for repairs in 2008 and unusually high inflows and resulting spillage in May and June 2009.

## **MODEL DESCRIPTION**

An analytical spreadsheet mass-balance model was developed to estimate the loss of coldwater storage in the reservoir due to the proposed increase in water appropriation from the current 0.75 mgd to 3.5 mgd and a periodic number of 1000 cfs whitewater releases, as specified by the Upper Potomac River Commission (UPRC). Whitewater releases are assumed to be 1 per month in June, July, and August at 1000 cfs for 6 hours each month. The model is based on data representing average and dry summer periods, running from approximately May-September, depending on available data. For each data interval (monthly to biweekly), the available coldwater volume was estimated for the temperature categories of <55 °F, <60 °F and <68 °F, based on temperature profiles for existing conditions and estimated increases in outflow for water supply diversions (WS) and whitewater releases (WW) in years in which these did not occur. Using this model, a calculation was made of expected coldwater volumes for the proposed higher water appropriation value, with and without specified additional whitewater releases. This information was then used to estimate outflow temperatures with the additional flows for WS and WW, based on measured reservoir bottom temperatures accounting for any additional depletion due to the increased withdrawals. This model does not directly account for heating and cooling that occurs within the reservoir. Measured temperature profiles are assumed to account for these processes as averaged over the approximately monthly to biweekly sampling interval. The model assumes that additional releases will use existing cold water storage at each increment until that increment is depleted. Once depleted, water of that temperature is no longer available and the release temperature will come from the next temperature increment.

## **RESULTS**

Availability of water of various temperature values was estimated for 1991, 2008, and 2009 using the available temperature profiles for those years. The COE had already done this for 2008 and 2009, so the same estimate was prepared for 1991 for the baseline case (actual inflow and outflow pattern for that year). For all years, a model was developed to predict temperature levels, assuming an additional diversion of 2.75 MGD (4.25 cfs) continuously from the first available temperature profile to the date of the last available profile. The model only used the station at the dam, since examination of the profile data at other stations indicates the reservoir is very nearly uniform in temperature from one end to the other. Cool water storage volumes are shown in Figures 1 through 3 for these 3 years. Results for 2008 and 2009 show no depletion of water less than 68 °F for the season, even with additional water supply diversions and whitewater releases. However, in 2009, 55 °F and 60 °F layers were depleted by late June to mid-July, respectively, due to high inflows in late Spring and resulting releases needed to prevent spillage. In 2008, 60 °F water was depleted about 2 weeks earlier with the additional water supply diversions than for existing conditions. In 2009, 60 °F water was depleted by mid-July, up to 3 weeks earlier with the additional water supply diversions and whitewater releases than under existing conditions. Results for 1991 show depletion of 68 °F water by about September 14, and 60 °F water by about September 3, which could have resulted in higher than required water temperatures in the river for trout, if the additional releases had been made that year.

These results also show effects of whitewater releases for 1991 and 2008 if they had actually occurred in those years (out of these 3 years, WW releases actually occurred only in 2008). Results do not account for any drought-triggered outflow reductions that would have occurred had ICPRB's PRRISM-predicted thresholds been implemented in those years.

Predicted outflow temperatures are shown in Figures 4 through 6 for 1991, 2008 and 2009, for existing conditions, with additional water supply diversions, and with whitewater releases; measured downstream river temperatures and outflow rates for existing conditions are shown for comparison. Results for 1991 (worst-case dry year) show no change in predicted outflow temperatures until September and only for whitewater releases in addition to water supply diversions for early September. Results for 2008 show minor increases in predicted outflow temperature in early August and mid-September with additional water supply diversions but not enough to affect trout habitat. Results for 2009 show virtually no changes in predicted outflow temperature with additional water supply diversions and whitewater releases.

## **RECOMMENDATIONS**

Based on these results, it is recommended that weekly to biweekly estimates of coldwater storage be continued during the summer months, based on measured temperature profiles in the reservoir. These estimates can then be used with the number of days remaining during the critical summer period to develop a trigger for a reduction in withdrawals when needed to protect downstream habitat. Such a trigger should allow for a low enough outflow temperature ( $<65^{\circ}\text{F}$ ) and/or sufficient minimum flow to maintain river temperature downstream of the dam to the Potomac River.

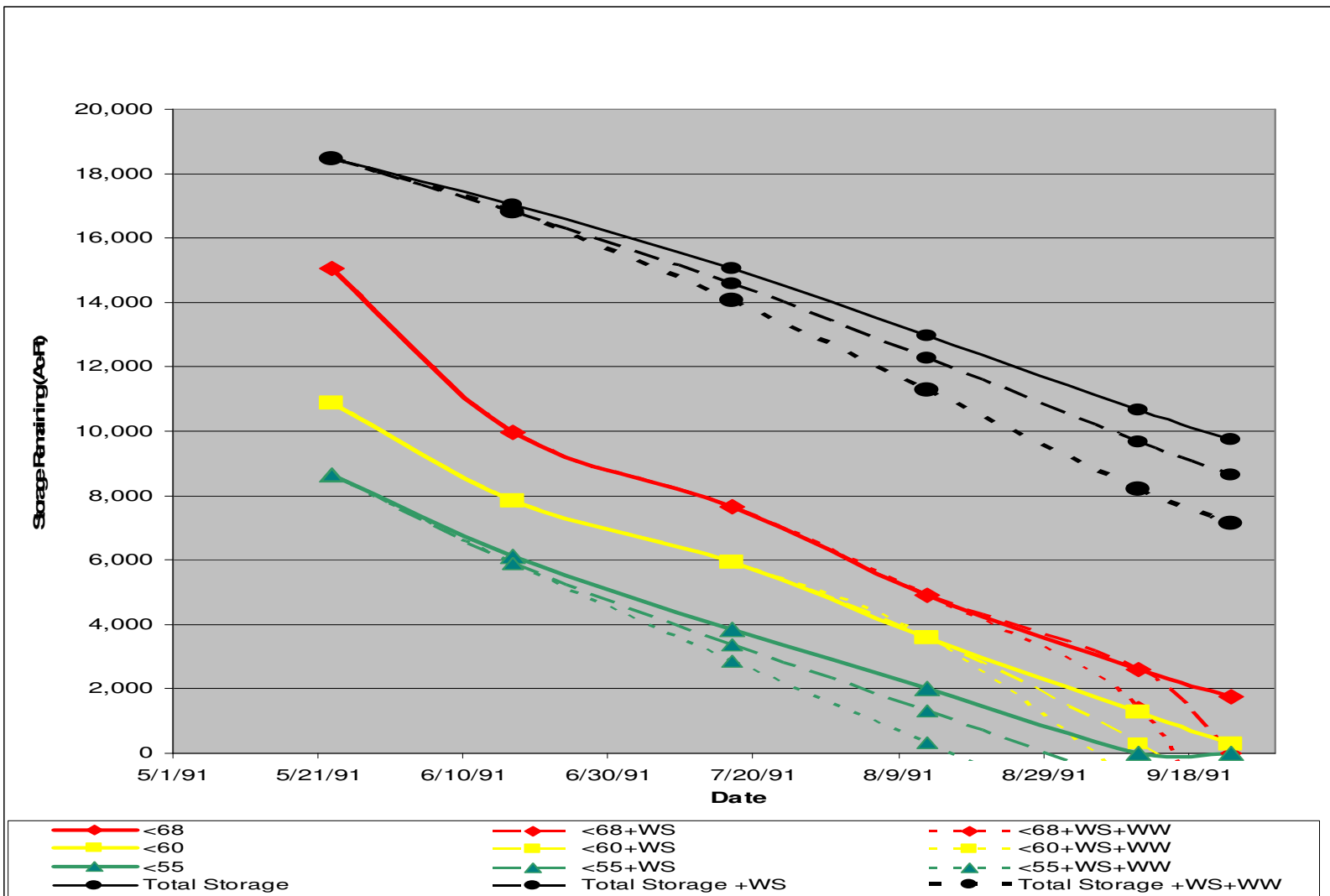


Figure 1. Savage River Reservoir cool water storage in 1991 (volume of temperature  $\leq$  °F indicated), as estimated from temperature profiles for existing conditions, with additional water supply diversions (+WS) and with additional whitewater releases (+WW). No whitewater releases were made in 1991.

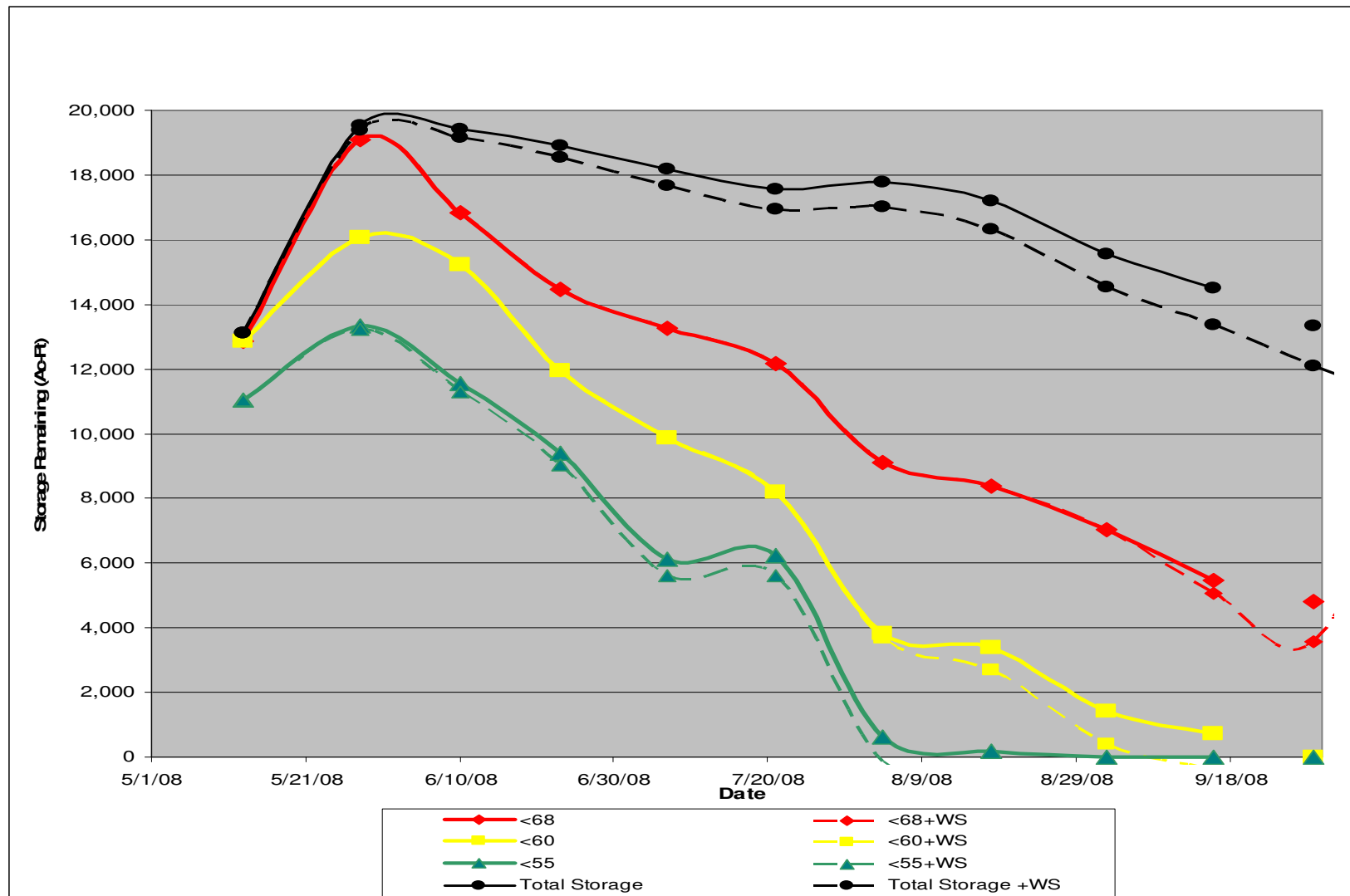


Figure 2. Savage River Reservoir cool water storage in 2008 (volume of temperature  $\leq$  °F indicated), as estimated from temperature profiles for existing conditions and with additional water supply diversions (+WS). Whitewater releases occurred in 2008 and are reflected in existing conditions.

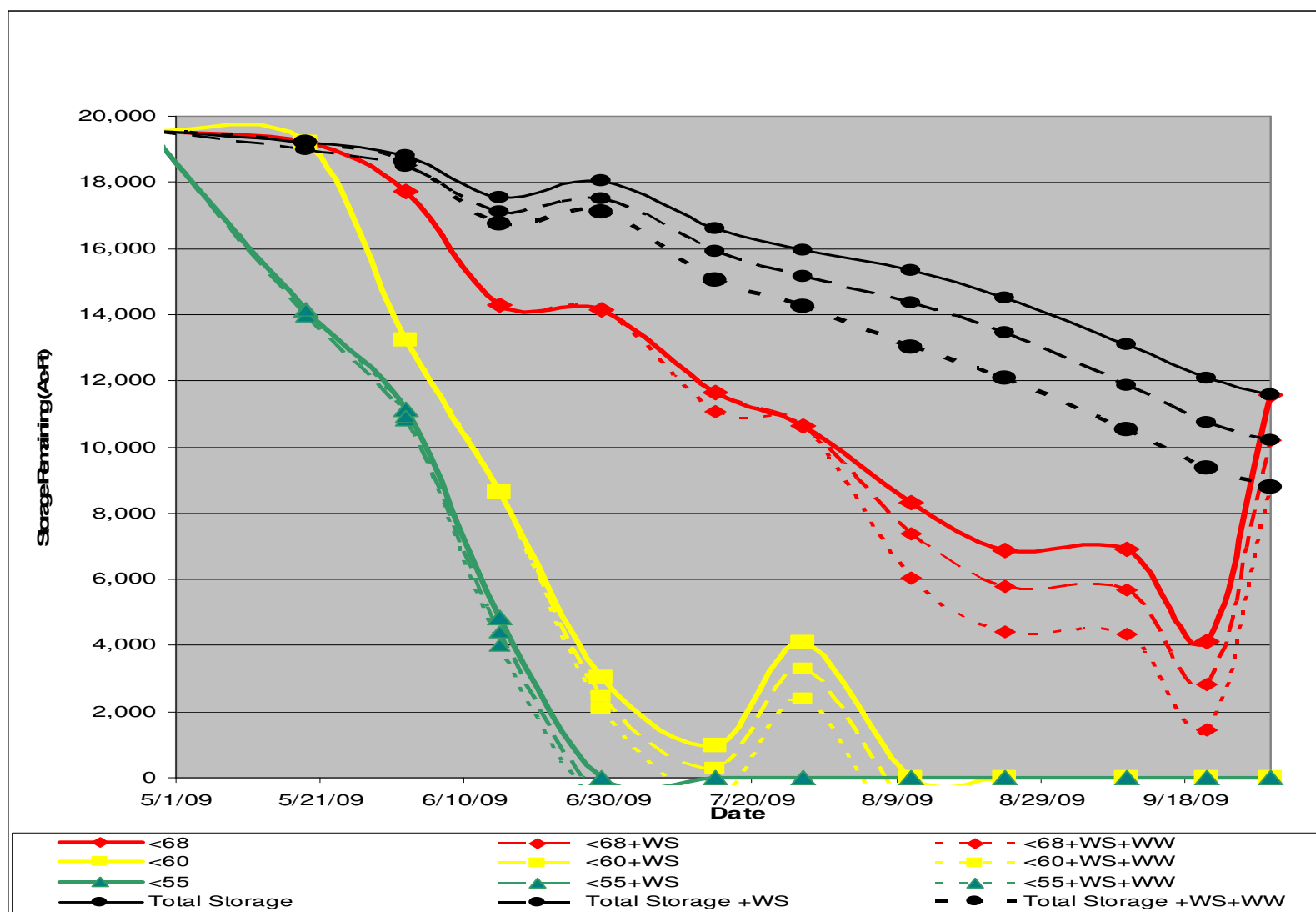


Figure 3. Savage River Reservoir cool water storage in 2009 (volume of temperature  $\leq$  °F indicated) , as estimated from temperature profiles for existing conditions, with additional water supply diversions (+WS) and with additional whitewater releases (+WW). No whitewater releases were made in 2009.

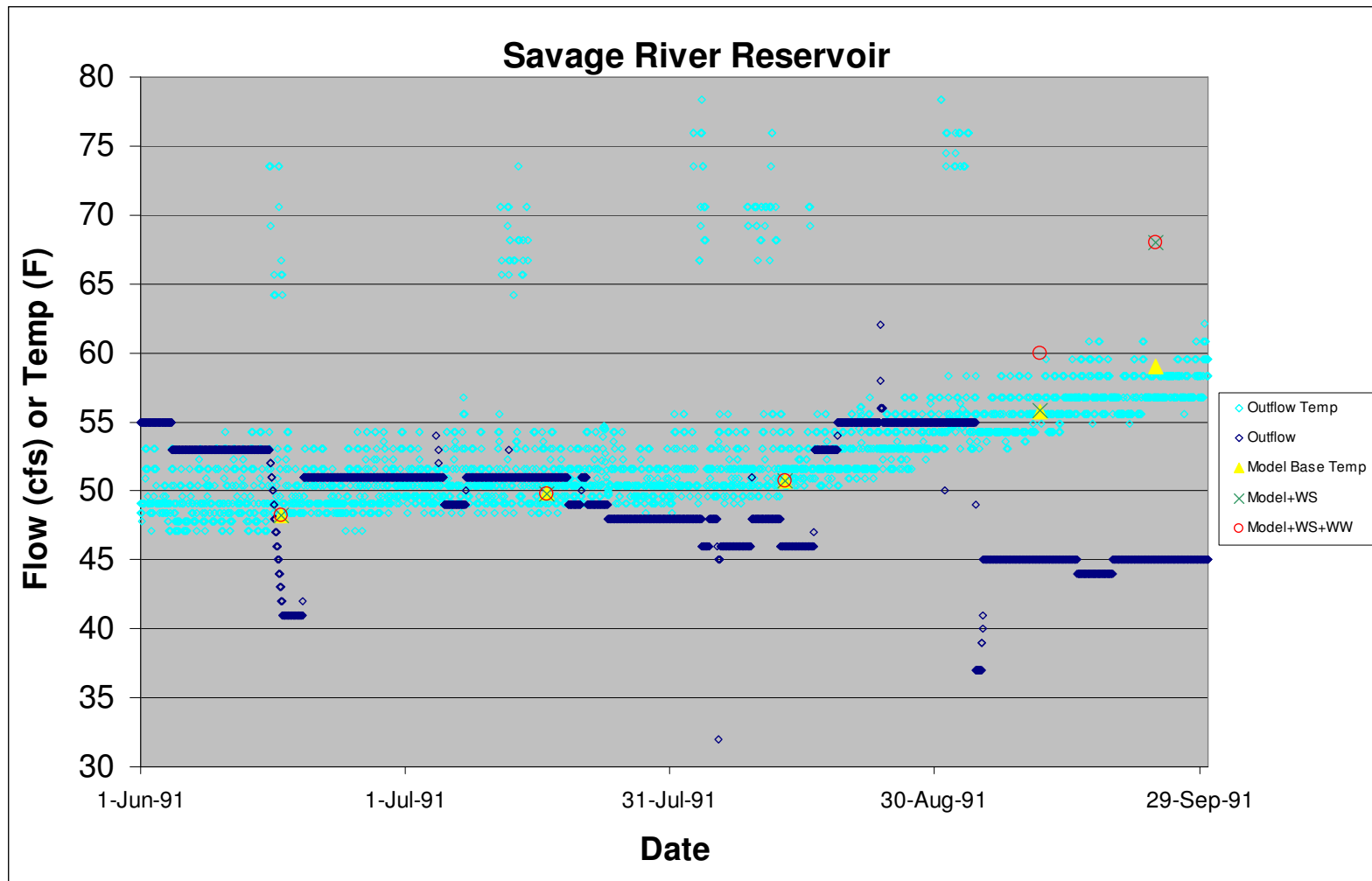


Figure 4. Savage River Reservoir predicted outflow temperatures in 1991, as estimated from temperature profiles for existing conditions, with additional water supply diversions (+WS) and with additional whitewater releases (+WW). Measured hourly downstream temperatures and flow are shown for comparison. No whitewater releases were made in 1991.

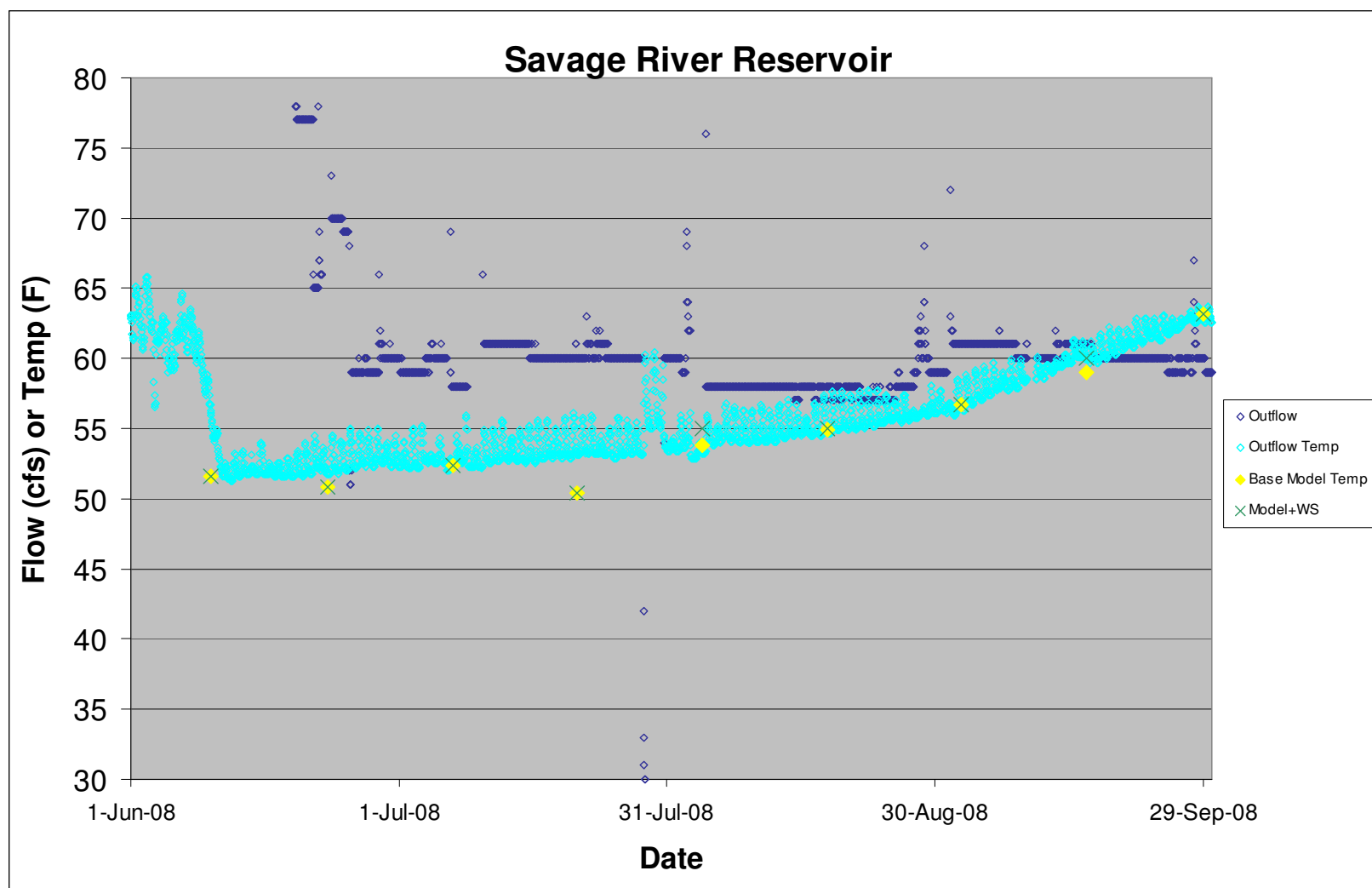


Figure 5. Savage River Reservoir predicted outflow temperatures in 2008, as estimated from temperature profiles for existing conditions, with additional water supply diversions (+WS). Measured hourly downstream temperatures and flow are shown for comparison.

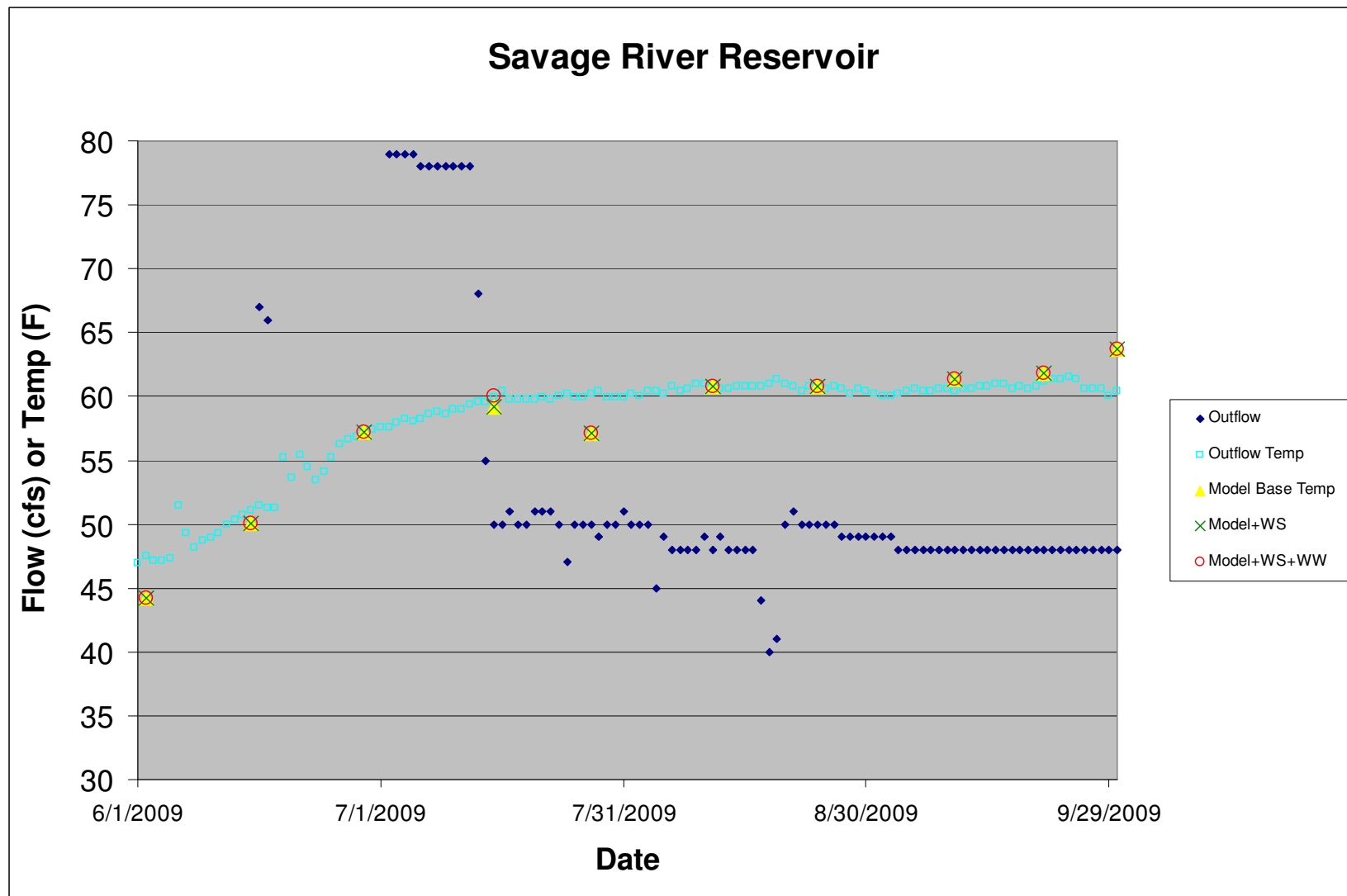


Figure 6. Savage River Reservoir predicted outflow temperatures in 2009, as estimated from temperature profiles for existing conditions, with additional water supply diversions (+WS) and with additional whitewater releases (+WW). Measured daily average downstream temperatures and flow are shown for comparison. No whitewater releases were made in 2009. (Note, only daily flow and downstream temperature date available.)